NRAC

Roles of Unmanned Vehicles

March 2003

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14. ABSTRACT

Over the past 20 years there has been a proliferation of unmanned vehicle (UV) research and development efforts and programs. Accordingly, the NRAC was asked to assess potential concepts of operations and employment across all naval missions with respect to unmanned vehicles. Specifically the panel was tasked to examine fleet needs, requirements, and desired capabilities and recommend which concepts are considered to have the greatest potential to improve warfighting capabilities and effectiveness, and reduce manpower and operating costs.

The panel arrived at the following conclusions: 1) the combat potential for the use of unmanned vehicles is virtually unlimited; 2) quantitative analysis and metrics are lacking; 3) Naval programs are not coordinated or focused; 4) lessons learned are not institutionalized; 5) cultural and policy obstacles exist.

From those the following recommendations are made: 1) create an integrated UV Master Plan; 2) conduct independent quantitative analysis; 3) institutionalize lessons learned; 4) create an integrated management structure to acquire UVs; 5) establish a policy for open systems architecture, modular design approach, and common man/machine interfaces; 6) focus on technology obstacles for next generation UV deployment.

15. SUBJECT TERMS

UV, UAV, UGV, USV, UUV, unmanned vehicles, CONOPS, master plan, modular design, manpower, persistant surveillance, sensors, robotics, reduced risk, counter-mine warfare, force protection, Sea Power 21, FORCEnet

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Naval Research Advisory Committee Report

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Roles of Unmanned Vehicles

Over the past 20 years there has been a proliferation of unmanned vehicles (UV) research and development (R&D) efforts and programs. These generally uncoordinated efforts have resulted in a plethora of unmanned systems in all operating environments—unmanned aerial vehicles (UAVs), unmanned ground vehicles (UGVs), unmanned surface vehicles (USVs), and unmanned underwater vehicles (UUVs). Increasing demands upon operating forces in terms of tempo, increased threat capabilities, rules of engagement parameters, and risk management are leading Naval Forces, as well as other services, to the development of and reliance on such systems. These UVs are envisioned to perform a variety of missions in many environments.

Study Scope and Methodology

In view of this, the Naval Research Advisory Committee (NRAC) was tasked by the Assistant Secretary of the Navy (Research, Development, and Acquisition) (ASN(RDA)) to form a study panel to assess potential concepts of operations and employment across all naval missions with respect to UVs. The Panel was tasked to examine Fleet needs, requirements, and desired capabilities and recommend which concepts are considered to have the greatest potential to improve warfighting capabilities and effectiveness, and reduce manpower and operating costs.

Although the time allotted to the Panel to complete this study was relatively short, the Panel was aided in completing its tasking by two factors. The first was the makeup of the Panel itself. As a whole, the Panel members represent almost 500 years of operational, technical, and managerial experience. Seven of the Panel are former Navy or Office of the Secretary of Defense (OSD) executives. Ten have had responsibility for major system development or acquisition. Five are former military who have had operational commands and decision making responsibility. Secondly, the Panel benefited from a robust fact finding and briefing schedule which included extensive briefings by both users (Navy, Marine Corps, Air Force, Army) and developers (Navy laboratories, warfare centers, Air Force and Army laboratories, Defense Advanced Research Program Agency (DARPA), industry) of UVs. Additionally, the Panel, in whole or in subgroups, visited seven commands directly involved in UV R&D.

The study methodology used in accomplishing the Panel's tasking was straightforward. The Panel was divided into subgroups by type of UV: UAV, UGV, USV, and UUV. Each subgroup then conducted a qualitative assessment (value and cost) to assess the contribution / applicability of their UV type for each of the Sea Power 21 Capability Areas (Persistent Intelligence, Surveillance, and Reconnaissance (ISR), Time Sensitive Strike, Information Operations, Expeditionary Maneuver Warfare, etc.). Based upon these assessments, specific findings and actions were proposed for each UV type.

Finally, based on the individual subgroup assessments, the Panel as a whole formed conclusions and made recommendations designed to facilitate improvement in the Department of the Navy (DON) approach to UV development and use.

Conclusions

The Panel came to the following conclusions with respect to UVs as a whole. Specific findings and actions for each UV type are included in the main body of the report.

- The combat potential for the use of UVs is virtually unlimited – UV systems can play a significant role in Persistent ISR, as communications nodes in netcentric warfare, and in unique areas as an augment to current force structure. Substantial reductions in warfighter risk are expected for time sensitive strike missions and some elements of tactical reconnaissance.

- Quantitative analysis and metrics are lacking – The Panel observed the lack of any formal quantitative analyses to justify the investments in unmanned systems. Similarly, the Panel found little in the way of metrics addressing the benefits of key aspects of unmanned systems. Both are considered essential to determine the most beneficial concept of operations (CONOPS) for initial and subsequent deployment of UVs.

- Naval programs are not coordinated or focused – The Panel found numerous Naval UV initiatives in development, funded from various sources. There is no master plan for USVs. Master plans for UAVs, UGVs, and UUVs exist in various levels of detail. All master plans appear deficient in planning life cycle total ownership costs and in sustainment of system capability on a forecasted, reliability-centered maintenance basis.

- Lessons learned are not institutionalized – The Panel could not find a systematic and coordinated Navy and Marine Corps effort to take advantage of the experience gained from experiments and demonstrations, including Advanced Concept Technology Demonstrations (ACTDs), Fleet Battle Experiments (FBEs), Advanced Warfighting Experiments (AWEs), or actual combat experience.

- Cultural and policy obstacles exist – Successful development of UVs faces cultural and policy issues. These include, for example, resistance to trusting a machine to perform tasks previously performed by humans, insecurity resulting from humans being displaced by machines, and development and application of a common Tactical Control Station.

Recommendations

The Panel proposes six recommendations to improve Naval development and use of UVs. Three are actionable at the Chief of Naval Operations (CNO) / Commandant of the Marine Corps (CMC) level and three are actionable at the Secretary of the Navy (SECNAV)/ ASN (RDA) level.

- Create an integrated UV Master Plan (CNO/CMC) – Designed to focus investment and speed the attainment of operational capability. This effort should identify the requirements for initial applications and develop plans for integration of these systems into the Naval Force.

- Conduct independent quantitative analysis (CNO/CMC) – The UV Master Plan must be accompanied by independent, quantitative analyses of the alternatives to conducting specific concepts of operations with and without UVs.

- Institutionalize lessons learned (CNO/CMC) – The Panel recommends that Commander Fleet Forces Command (CFFC) and the Marine Corps Combat Development Command (MCCDC) be made both the repositories for lessons learned and the action agents to ensure they are implemented in the UV Master Plan, future exercises, and in future systems.

- Create an integrated management structure to acquire UVs (ASN (RDA)) – Organizational alternatives should be explored and a structure implemented that will establish design principles and standards, create and maintain test beds, and enforce compliance.

- Establish a policy for open systems architecture, modular design approach, and common man/machine interfaces (SECNAV) – Ensures maximum possible benefit from interoperability.

- Focus on technology obstacles for next generation UV deployment (Deputy Assistant Secretary of the Navy (DASN)/Program Executive Officer (PEO)/Chief of Naval Research (CNR)) – Focus science and technology (S&T) efforts on the following five highest priority technology enablers: cooperative adaptive autonomous controls, intelligent information management, secure robust communications, energy storage and propulsion for endurance, and launch and recovery systems.

Concluding Remarks

There is no question that the Fleet/Force of the future will be heavily dependent upon UVs. Many will be organic to surface and submarine combatants and many will be in a ready for issue role to fleet units, areas of responsibility and/or combat zones around the world. Development must be in compliance with an interoperable architecture and the networking necessary to integrate UVs into Sea Power 21's elements: Sea Shield, Sea Base, and Sea Strike. Implementation of this study's recommended actions will ensure that future naval forces have available to them an effective and affordable suite of UV systems that complement our manned capability and effectively respond to the ever changing threat and character of combat.

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Terms of Reference

- **Review and assess potential concepts of operations (CONOPS) and employment (COE) of Unmanned Vehicles in all Naval Missions.**

- **Examine:**
  - **Fleet Needs and Requirements**
  - **Desired Capabilities**
  - **Affordability**

- **Recommend which concepts are considered to have greatest potential to:**
  - **Improve Warfighting and Effectiveness**
  - **Reduce Manpower**
  - **Reduce Cost of Operations**

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TERMS OF REFERENCE

The Panel reviewed the utility and effectiveness of UVs in all Sea Power 21 mission areas and identified those in which benefits were considered achievable. The approach and metrics used in this analysis, which was qualitative in character, will be discussed later.

The Panel felt they did a credible job of determining how and where UVs could be used to replace or compliment manned systems. They also attempted to identify the obstacles− technology, cultural, and operational−that needed to be addressed and overcome. Due to the limitations of time and data, the Panel was unable to address affordability in a meaningful way.

The Panel identified a number of concepts which are considered to have immediate potential to (1) improve warfighting capabilities and effectiveness, (2) reduce warfighter risk, manpower requirements, and cost of operations, and (3) to save lives.

The complete Terms of Reference (TOR) is at Appendix A.

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Panel Participants

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- **Joseph J. Eash (Col USAF Ret)**
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- **Dr. Elihu Zimet**

Executive Secretaries:
- **CAPT Jeffrey Jones, USN**
- **CDR Michael Crowley, USN**

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PANEL PARTICIPANTS

These are the Panel members.

They represent almost 500 years of operational, technical, and managerial experience. Seven of the Panel are former Navy or OSD executives. Ten have had responsibility for major system development or acquisition.

Five are former military who have had operational commands and decision making responsibility.

The credentials of the Panel members and the approach taken in response to the tasking, provides rationale and justification for their findings and recommendations.

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Briefings and Visits

- **Received 38 Briefings/Visited 7 Commands**

- **Users - Navy, Marine Corps, Air Force, Army (Warfighters, Oceanographers, Security Forces)**

- **Developers - Navy Labs, Warfare Centers, Air Force, Army, DARPA, Industry**

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BRIEFINGS AND VISITS

The Panel Chair met with the OPNAV Sponsor, RADM Lewis W. Crenshaw, Jr., (N81), and received approval of the study approach in June 2002. Meetings with users and developers began in July and continued through September.

Considerable interaction with the major defense contractors, who have developed and built all the manned systems, revealed their assessment of the potential of UVs to satisfy the needs of future Naval Forces. They are optimistic about the future utility of UVs, in the military and the private sector, but appear frustrated by the lack of focus or direction from the Navy. Military users are optimistic about the potential of UVs. Optimism appeared to be based on a mixture of fact, (Predator) and hope (Global Hawk, Dragon Eye, and Dragon Warrior) and the expectation that UVs can do things and go into situations where human or human operated systems cannot, or, because of very high risk, should not.

Users and developers identified their hope that UVs could be used in dull (broad area long endurance surveillance or sentry missions), dirty (areas contaminated with chemical, biological or radioactive agents) or dangerous (clearing caves, buildings, mines) environments. Industry and government developers are convinced that the technology required to field first generation systems is in hand but that technology advances would significantly improve utility and effectiveness by permitting increased autonomy in operations, less burdensome launch and recovery, increased operating range and/or endurance.
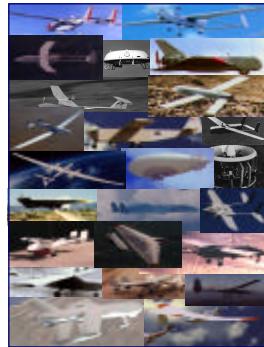
These briefings and visits were the source of the data used by the panel to review and analyze the potential applications of UVs in future Naval warfare.

The complete list of visits and briefs is at Appendix D.

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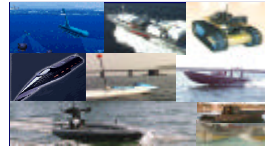
Unmanned Vehicles Today

Aerial Vehicles (> 120)
Joint Master Plan

Underwater Vehicles (> 70)
DON Master Plan

Ground Vehicles (> 50)
Joint Robotics Master Plan

Surface Vehicles (>10)
No Master Plan

Characteristics

- Unique Designs
- Unique Payloads
- Little/No Interoperability or Modularity
- Separate Unmanned System Master Plans

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UNMANNED VEHICLES TODAY

UVs are divided into four categories that are distinguished by the medium within which they operate—air, ground, water surface, underwater. Three factors combine to provide a dazzling array of alternative platform types. First, the technology exists for first generation capability. Second, except for large UAVs where there has been substantial government investment, it costs relatively little to produce a platform prototype. Third, there are a large number of interested investors, both military and commercial.

In the UAV world there are currently more than 120 vehicle types that range from 40 pounds to almost 27,000 pounds with endurance from tens of minutes to 35 hours and with operating ranges from a few to thousands of miles. In the UUV arena approximately 70 types exist that vary in size from nine inches in diameter and three feet long to eight feet in diameter and 50 feet long. UUV endurance varies from a few hours to several days. UGVs are also proliferating, driven by both military and commercial applications. Currently 50 UUV platforms have been identified. These, too, vary in size from approximately 20 pounds to 60 tons. There are also a small but growing number of USV types.

Virtually all of these systems have been developed to perform a specific mission or set of functions. Each represents a point design with little, if any, attention paid to the utilization of standard physical interfaces, provision for modular payloads, or employment of a common control architecture. Appendix (B) depicts those UV systems that were reviewed by the panel and lists the missions to which they apply and the phase of acquisition which they are in today.

There are varying phases of maturity with respect to a roadmap for the future employment of UVs by Naval Forces. A Joint Master Plan exists for UAVs. Since the Navy is the only service that will deploy UUVs and USV's, it has the responsibility for creating

these roadmaps. A DON Master Plan exists for UUVs, but none exists for USV's. Driven by OSD and involving all the services, a Joint Robotics Master Plan exists for UGV development. A comment on the UAV plan appears later in this report. There is no Navy document that stipulates UV requirements for interoperability, compliance with FORCEnet, physical interface standards or an open systems architecture.

The problem is not a lack of options, but that direction and discipline are needed to provide to focus investment in order to address the highest payoff missions.

Executive Commitment to Unmanned Vehicles

"My budget calls for the largest increase in defense spending in the last 20 years, investing in more precision weapons, missile defenses, <u>unmanned vehicles</u>, and high tech equipment for our soldiers on the ground."

President George W. Bush - 26 January 2002

"As we change investment priorities, we have to begin shifting the balance in our arsenal <u>between manned and unmanned capabilities</u>, between short and long-range systems, stealthy and non-stealthy systems, between shooters and sensors, and between vulnerable and hardened systems."

Secretary of Defense Donald Rumsfeld - 31 January 2002

"<u>Unmanned systems</u> are now on the threshold of delivering on the promise of transforming our military, and likely, our society."

Secretary of the Navy Gordon England - 31 July 2001

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EXECUTIVE COMMITMENT

These quotes are examples of the many comments that have been made by political and military leaders regarding UVs.

The Panel believes that the statements are based, in part, on the success achieved with UV systems like Predator, and UGVs that explored caves in Afghanistan and searched for survivors at the World Trade Center. The Panel further believes that these leaders recognize that UV systems have the potential to change the way future conflicts are fought—by using UVs to go into situations; where humans cannot—where the danger is so great that we don't want to risk humans—when mission requirements exceed the limits of human endurance—or to reduce manpower requirements by augmenting or replacing humans with UVs.

These visionary statements are considered to be foresighted and appropriate for these and other reasons which will be discussed on the next chart.

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Opportunities for Naval Unmanned Vehicles

- **CAPABILITY**
  - Endurance, Scale (micro to macro), Agility, Fearlessness
- **THREAT**
  - Less Sophisticated yet Dangerous
  - More Dispersed and Elusive
- **CULTURE**
  - Casualties (operator, friendly, non-combatant & enemy)
  - Instant Information and Performance
- **LEVERAGE TECHNOLOGY WHILE UNRAVELING THE COST SPIRAL**
  - Autonomy
  - Government & Commercial Investments
  - Design Philosophy (Modularity, Open System Architecture)

Reduce User Risk	Improved Intelligence	Comm. Nodes
Unique Capabilities		Endurance
Reduce Training	Reduced Manpower	Lower Cost

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OPPORTUNITIES FOR NAVAL UNMANNED VEHICLES

The Panel concludes that progressively maturing UV capabilities, coupled with changes in the threat, cultural and technical climates, provide a superb opportunity for the development and fielding of a broad range of effective Naval UVs.

Recent UV demonstrations and operations revealed that UVs offer a powerful capability to our warfighters. UVs are particularly attractive due to their extended endurance, range, agility, fearlessness and scalability (micro to macro). UVs have demonstrated performance capacities exceeding manned systems thus providing broader operational capability. The ability of UVs to remain on station for days conducting quality surveillance, with no operator risk, is a valuable and needed capability. The evolving threat now includes less sophisticated, yet more elusive, adversaries that are capable of acquiring and using advanced weapons. The ability of UAVs to provide persistent surveillance and deterrence has been demonstrated in Afghanistan. On the ground, UGVs are demonstrating their value in dangerous missions like cave exploration and mine clearing.

U.S. political and civilian culture has evolved to expect minimum U.S. casualties. Concurrently, battle dominance is expected without friendly fire incidents or unacceptable collateral damage. Real time visualization of the battlespace is now assumed. UVs have emerged as promising tools for use in the achievement of these very challenging expectations.

A unique opportunity exists now for the development of effective Naval UVs. Demonstrator UV systems have been tested with success in military operations. Technologies for capable sensors and robotics have emerged from the significant government and commercial investments and developments in electronics and computers. The opportunity exists to specify Command, Control, Communications, Computers and

Intelligence (C4I) infrastructure, open system architecture and modular design. Development of the next set of UVs is technologically achievable. Within five years Naval forces could field highly capable UV systems reducing operator risk, with lower manpower requirements and operational cost, while enhancing operational effectiveness. UVs could play a major role in the increasingly dynamic battlespace of the 21st century.

Study Methodology

- **Subgroups (vehicles)**
    - **UAV (BAMS, Pioneer, UCAV-N, Dragon-Eye)**
    - **UGV (Gladiator, Dragon Runner, Army & OSD projects)**
    - **UUV (LMRS, RMS, REMUS, SAHRV, SEAHORSE)**
    - **USV (Spartan, Owl, Roboski, and target drones)**

- **Approach**
    - **Assessed UV utility for Sea Power 21 Capabilities**
    - **Performed Qualitative Assessment (value and cost)**
    - **Identified Specific Findings and Actions**
    - **Made General UV Observations**
    - **Recommended Actions**

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STUDY METHODOLOGY

In order to efficiently review the many candidate unmanned systems, the study group was divided into 4 subgroups, corresponding to four types of UVs. Each subgroup focused on the UV systems believed to have a highest prospect for application to Naval missions. The specific systems reviewed are shown in parentheses on this chart.

Next, the subgroups qualitatively rated each candidate UV type against the Sea Power 21 list of desired capabilities, and their ratings were grouped as having high, medium, and low payoff.   The results of these ratings will be shown on the UV Mission Analysis viewgraph on page 23.

In order to recommend investment for specific UVs, each was reviewed for its goodness against its potential value as well as elements of cost.   The sub-elements of value and cost will be shown on the next viewgraph.

Each subgroup arrived at specific findings and actions related to candidate UVs as well as identifying some issues that are common to the UVs in their subgroup or UVs in general.

Finally, the study group arrived at a few high level recommendations that will insure that the potential for unmanned systems will be achieved in their operational use.

The next chart will provide the detailed categories used in the qualitative evaluations.

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Review Factors

Capability Areas	Value Elements	Cost Elements
Persistent ISR	Total Cost Savings	Development
Time Sensitive Strike	Reduced Manning	Acquisition
Information Ops	Mission Effectiveness	Sustaining
Expeditionary Maneuver Warfare	Reduced Warfighter Risk	Operations
Theater Air & Missile Defense	Time Critical Knowledge	Replacement
Littoral Control	Joint & Combined Ops	Training
Homeland Defense and Force Protection	Multi-Function	
Accelerated Deployments & Employment	Cannot Be Done By Humans	
Enhanced Positioning		

Capability Facilitator

FORCEnet

REVIEW FACTORS

The nine Sea Power 21 Mission capabilities are shown in the first column on this viewgraph. The UAV, UGV, USV, and UUV working groups made a qualitative judgment of how well their vehicle types benefited each of the mission capabilities. The subgroups also assessed how well the FORCEnet complements UVs. The results of these assessments will be shown on the next viewgraph. The Panel recognized that the performance of a UV for a single mission is not the only factor to be considered in coming up with their recommendations.

Therefore, in addition to qualitatively estimating the mission value of each unmanned system, the subgroups attempted to estimate the UVs value in terms of general benefits, applicable across missions. The general benefit categories are listed in the second column on this viewgraph. In this list Total Cost Savings is identified as one of the value metrics. The qualitative estimate of cost savings is an estimate of the cost difference between using the unmanned system versus a manned system. Therefore, it is listed in this case as an asset as opposed to a debit. The other value elements are self explanatory benefits of unmanned systems.

The cost elements shown in the last column of the viewgraph are the final review factors that the subgroups considered. In this case the cost is a debit and represents a qualitative estimate of each element of the total cost of ownership of the UVs.

Finally, the subgroups prioritized the various unmanned system candidates based upon the relationship between the value and the cost elements. As such a UV with high value and low cost would be most desirable and a system with low value and high cost would be the least desirable.

The next chart shows how the UV types rated against SeaPower 21 capabilities and interfaced with FORCEnet.

Unmanned Vehicles Mission Analysis

	UAV	UGV	UUV	USV
• **FORCEnet - the Joint Ops Enabler**	HIGH	HIGH	HIGH	HIGH
• **Sea Strike**				
– **Persistent ISR**	HIGH	MED	HIGH	HIGH
– **Time Sensitive Strike**	HIGH	HIGH	LOW	N/E
– **Information Operations**	MED	MED	N/E	N/E
– **Expeditionary Maneuver Warfare**	HIGH	HIGH	MED	LOW
• **Sea Shield**				
– **Theater Air & Missile Defense**	HIGH	N/E	N/A	N/E
– **Littoral Control**	MED	HIGH	HIGH	MED
– **Homeland Defense**	LOW	LOW	LOW	HIGH
• **Sea Basing**				
– **Accelerated Deployment and Employment**	N/E	LOW	N/E	LOW
– **Enhanced Sea-borne Positioning of Joint Assets**	N/E	N/A	N/E	N/E

N/E - Not Evaluated   N/A - Not Applicable

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<u>UNMANNED VEHICLES MISSION ANALYSIS</u>

Based on the SEA POWER 21 vision, the Navy and Marine Corps have developed a transformational roadmap comprised of nine operational capabilities within three warfighting missions. Sea Strike projects timely, decisive and persistent, offensive power anywhere in the world. Sea Shield assures access and projects defense. Sea Basing projects forces worldwide and pre-positions joint assets. FORCEnet is the information networking and processing that enables netcentric warfare in support of the other three missions.

Using the Review Factors of Value Elements and Cost Elements, the Panel has provided a qualitative assessment of the utility of UVs to enable these nine capability areas. The relative values of High, Medium and Low in the matrix show the Panel's appraisal of the potential value of unmanned systems in each of these capability areas. The fact that an area is marked as not evaluated (N/E) does not necessarily imply that UVs have no role to play. The Panel simply felt that it was not as clear that UVs could make a critical difference.

A top-level assessment of the qualitative analysis provides the following insights:

• All UVs are conceived as being nodes in the network, and in this sense they are an integral part of FORCEnet. UVs that are sensor or communication relay platforms are critical parts of the network.

• The ability to operate in high threat areas provides a unique opportunity for UVs to provide Persistent ISR and this capability is considered their highest overall value for many types of vehicles.

• The ability of UVs to contribute to counter-mine warfare and provide security in the littorals strongly enhances their utility for Littoral Control.

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- As Rules of Engagement (ROE) are developed and technological advances are made in Automatic Target Recognition (ATR), UVs will play an increasing role in Time Sensitive Strike.

- The Marine Corps is committed to the utility of UVs for Expeditionary Maneuver Warfare.

UAV Findings and Actions

- **Marine Pioneer PIP**
  - **Expedite, Procure, and Field the Marine Pioneer(PIP) UAV**
  - **Retain Amphibious Shipboard Capability**
  - **Utilize TCS / TCDL for Interoperability**
- **Broad Area Maritime Surveillance (BAMS)**
  - **Realign BAMS Schedule with Global Hawk Demo, AOA and CONOPS**
  - **Utilize TCS**
- **UCAV-N**
  - **Realign UCAV-N Schedule to absorb Air Force UCAV Demo Results**
  - **Develop CONOPS and AOA**
  - **Evaluate Shipboard and Operational Compatibility**
- **Leverage JUAV-JTE for Development of Joint Autonomous Systems,Tactics, and CONOPS**

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UAV SPECIFIC ACTIONS

Today the only operational UAV systems in the DON are the two squadrons of Marine Corps Pioneers and the one detachment of Navy Pioneers (presently not ship deployed) which were first fielded in the late 1980's. Pioneer is a proven system for providing the operational commander in the field with real time ISR. Used in all conflicts from the Gulf War through Kosovo (Operation Just Cause), it could benefit significantly from technology insertion to update its old analog mission control stations and several air vehicle components. These performance and reliability updates are planned and budgeted for in the Navy's Program Objective Memorandum (POM) 2004. The key deficiency is the lack of a tactical UAV system capability afloat for support of naval missions. It is the Panel's strong recommendation, based on the operational needs of our warfighters, to integrate Marine Corps Pioneer Product Improvement Program systems into the Expeditionary Strike Groups (ESGs) to provide real time, netted, ISR enabling capabilities to support Sea Strike and Sea Shield.

The Navy's plan for long dwell, persistent, real time, high altitude ISR, tracking, signals intelligence, and communications/data relay is a two-phased program. The first phase is the purchase of two Global Hawk systems from the U.S. Air Force with their Mission Control Element (MCE) shelter, Launch and Recovery Element (LRE) shelter, and autonomous control system and data link. The plan is to buy the two Global Hawk systems, taking delivery in FY 2005, and begin evaluations with FBE Mike in late FY 2005 and Team Spirit in FY 2006. The second phase is the acquisition program for the Broad Area Maritime Surveillance (BAMS) system, culminating in delivery of R&D systems and start of developmental testing/operational testing (DT/OT) in FY 2006. The issue raised by the Panel is that the schedules for these two efforts do not match up in a way that will allow useful information from the Global Hawk demonstrations to feed into the CONOPS and

Abbreviated Operational Assessment (AOA) work for BAMS. There will not be sufficient data available to answer the question "is the Global Hawk vehicle and its spiral development planned changes good enough to meet the Naval needs and requirements?" Therefore, the Panel felt that the BAMS schedule needs to be adjusted to take advantage of the Global Hawk demonstration results.

The issue of real time information dissemination in the netcentric architecture also dictates that the Global Hawk demonstration and ultimately the BAMS program incorporate the Joint Requirements Oversight Council (JROC) approved Tactical Control System (TCS) to enable the FORCEnet benefits to Sea Power 21 missions.

The Panel has similar concerns about the timing of the Unmanned Combat Air Vehicle – Navy (UCAV-N) program. The US Air Force / DARPA UCAV program will deliver R&D vehicles in FY 2004 to begin evaluation of mixed manned and unmanned airspace management, weapons delivery, and flight and field operations. The concern is that lessons learned from the Air Force UCAV development, that would have applicability to the UCAV-N program, will not be available until after the Contractor Evaluation (CE) program is completed and, in some areas, not until after the Milestone B (Engineering Manufacturing Development (EMD)) phase of UCAV-N has begun.

There are major differences in overall concept between the Air Force and Navy programs that the Panel feels should be addressed through detailed modeling and simulation (M&S) and prototype evaluations. These include carrier suitability, deck movement, supportability operations in a mixed manned and UV environment and the very critical launch and recovery operations of an autonomous or semi-autonomous platform.

The Panel strongly recommends adjustment of the UCAV-N schedule to permit incorporation of the lessons learned of common operations between the two service concepts and ample time to do the detailed M&S and carrier suitability evaluations prior to starting an EMD acquisition program.

The Joint UAV-Joint Test and Evaluation (T&E) Unit at the Naval Strike and Air Warfare Center (NSAWC), Fallon, Nevada is the ideal organization to accelerate the operational and cultural integration of UAVs into Naval Forces. They utilize a family of UAVs and extract user experience in daily operations with air wings as they train prior to deployment. From this they develop and evaluate CONOPS, ROE, airspace management procedures, and training content. As the sole Joint UAV organization in DOD, the Joint UAV-Joint T&E Unit will oversee and direct UAV operations with manned aircraft, and will be the primary contributor to the CONOPS development for BAMS and UCAV-N. The Panel recommends total support for this OSD chartered and funded unit and notes the importance of having the "lessons learned" transferred to Naval Warfare Development Command (NWDC) and Navy and Marine squadrons to improve the quality and output of the FBEs, AWEs, and for use in development of the UV Master Plan.

UGV Findings and Actions

- **Sensing Systems have High Payoff for Moderate Cost**

- **Autonomous Shooting Systems have High Payoff but for Highest Cost**

- **Support Systems have Moderate Payoff for Low Cost**

- **Dragon Runner is a promising Sensing System for Urban and Subterranean Operations**
  - Needs more experimentation and CONOPS development

- **Gladiator is a Teleoperated Multi-Mission System**
  - Detailed implementation plan exists with fielding in FY06
  - Evolutionary product upgrades need to be red teamed

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UGV FINDINGS AND ACTIONS

Unmanned ground systems are ideally suited for many types of sensing missions. For example chemical, biological, radiological, nuclear, and explosive detection are extremely hazardous missions for humans and require close proximity for detection. Acoustic and seismic detection also benefit from proximity to the source which UGVs can provide. A wide variety of sensors exist both in the military and commercial arenas that can be applied to UGVs. The investment to apply these sensors to unmanned systems is driven by integration, communication and processing.

The Panel believes that the shooter UGV has a very high payoff for limited field of view environments such as urban warfare and counter-sniper environments. Because shooting systems will require high resolution sensing sub-systems, a reliable command and control sub-system, a weapon sub-system, with an extremely reliable on board logic system, the cost will be significantly greater than other UGVs. In addition the UGV platform will be operating in an environment that will require a protective system which will also increase the cost. The integration of this type of system into the force will be more complex than other UGVs.

Support systems for cargo handling and hauling exist in the commercial sector and should be readily transferable to military applications at little development cost. The further forward these systems are used, and the more cross country capable, the greater the need for Department of Defense (DoD) investment. Support systems for internal physical security are being deployed in the commercial area for guard patrol. The DoD is extending this capability to external environments and considering non-lethal response payloads. An additional mission of this type of UGV would be for force protection. The other types of support systems that were considered by the UGV Panel were countermine, breaching (barricade and building), and explosive ordnance disposal.

Dragon Runner is an eight pound, low cost man portable UGV with day/night video, image motion sensors, and acoustic monitoring to provide reconnaissance and surveillance in confined areas. It is designed to be thrown into a building or cave and operates even when upside down. It will greatly benefit from lessons learned in experiments and operational deployments, and once the Marine Corps is comfortable with its CONOPS, could become widely deployed.

Gladiator is a Marine system in the mid size range. The Gladiator will operate forward of Marine units, performing combat tasks such as reconnaissance, scouting, target acquisition (RSTA), obstacle breaching, nuclear, biological, and chemical (NBC) reconnaissance, direct fire, and engineer reconnaissance. Currently, Gladiator is scheduled to be fielded in FY06. A detailed plan exists to make several product improvements to the basic system. The panel believes that an independent assessment of the order in which the product improvements will be made would be advisable.

UUV FINDINGS AND ACTIONS

The importance and potential of UUVs is well understood by the warriors, particularly the submarine force. The technology is mature. A master plan for development and introduction of UUVs into the Navy has been approved. This plan is updated at two-year intervals to ensure its currency.

The efficient hydrodynamic shape of UUVs provides a degree of low observability as does their operating underwater. A low noise signature is, of course, also desirable.

A qualitative analysis reveals that the highest near-term payoffs for UUVs are in inshore mine warfare, anti-submarine warfare, and oceanographic survey roles. Intelligence, surveillance, reconnaissance, communication nodes, and force and port protection are certainly within the capabilities of UUVs. As higher energy sources become available a track and trail capability will be developed. Oceanographic surveys in the civil sector, mostly the offshore oil and gas industry, are routinely conducted today using UUVs today. The underwater communication cable industry also uses UUVs for location and survey.

The endurance of UUVs is a critical factor. Even though reasonable endurance is available in UUVs using energy sources available today, improved energy sources are needed to realize their full potential. Batteries of various chemical compositions are the primary energy source of most UUVs. The Remote Mine-hunting System (RMS) is not a true UUV because it uses a diesel engine with snorkel protruding to the surface. Higher energy sources, batteries and fuel cells, are in development. Hopefully the enormous amounts of funds being spent by the automotive industry will result in compact, low weight, higher energy sources that can be used in UUVs. Navy R&D funds support some research in the area, but it is a trickle compared to automotive industry efforts. The modular architecture of UUVs can contribute to improved endurance. Multiple energy modules could be

employed to increase available energy. A modular approach is usually considered in terms of payload or mission related sensors. However, tail-end modules for propulsion systems to meet mission maneuverability requirements also exist as do front end sensors for obstacle avoidance and/or search. A modular UUV architecture permits tailoring the UUV to fit the mission.

Acoustic communications in water to/from UUVs is range limited. This limits UUV interoperability with other manned or unmanned systems. There is a need to improve high-bandwidth underwater communications capability to correct this limitation. Improved sensor packages and navigation systems are ongoing efforts to enhance UUV multi-mission roles. An improved sensor to detect bottom and buried mines is a priority.

Surface launch and recover systems are rudimentary at best. Most are afterthoughts, making do with existing boat davits. This deficiency is a factor in the surface community's reluctance to embrace an organic capability involving launching and recovering UUVs from surface ships. A unique, well engineered, launch and recovery system exists in submarines for the Long-range Mine Reconnaissance System (LMRS).

A relatively large number of UUVs are in various stages of development within the Navy. Many are duplicative. However, knowledge is gained from each effort, which contributes to the total UUV effort. Better coordination of these efforts and communicating lessons learned to the entire UUV community is desirable.

As mentioned above, the offshore oil, gas, and communication industries, both domestic and foreign, have spent and are continuing to spend large sums of money in developing UUVs for their use. The Navy should continue to encourage the flow of technology into the Navy from these civil sectors.

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USV FINDINGS AND ACTIONS

Of the four UV areas reviewed, the Panel found that there appears to be less activity in USVs than in any of the other three and that there is no overall development plan in existence. Although the Naval War College report of the Global 2001 war game stated that "USV's were key contributors in establishing situational awareness in the littoral and have shown the potential to provide critical access to high risk areas", the Panel saw little evidence of this being exploited except in a conceptual context. Three platforms are in various stages of development at the naval warfare centers and laboratories: (1) a 25-35' Spartan, (2) a 10' Owl, and (3) a 6' Roboski, as well as several target drones. All are being tested in the mine and anti-submarine warfare areas, incorporating limited ISR applications. Although they were briefed and discussed, the NRAC saw little evidence of any efforts being made to counter small boat swarm attacks. Never-the-less, it does appear the technology needed for USV's to carry out the Sea Power 21 mission areas is mature and available in the near term, and that USV's provide long endurance, low observability, agility, and high speed at a relatively low cost.

When analyzing the Sea Power 21 mission areas, it was found that the highest near-term payoff for USV, understanding the limited data available, is in port and ship security. They have the potential to reduce or eliminate the need for manned rigid inflatable boats operating off piers and around ships at anchor, as well as for doing the same for sea side pier sentries. An Owl type vehicle could be remotely controlled or programmed for autonomous operation. The savings in manpower alone would be significant, and the vehicles, with sensors, are more than affordable and could be easily carried by all surface combatants.

As the U.S. Navy moves forward with developing the Littoral Combat Ship, having as three of its priorities, mine inshore warfare, anti-submarine warfare and countering small boat swarm attacks, USVs potentially can play a significant role. More work needs to be

done in these areas, and it should be integrated with UUV efforts to ensure the best capability for the dollar is achieved. Stability, sea-keeping and visual field-of-view are issues requiring further evaluation for USVs. However, it is believed that these will only be marginal constraints compared to developing a satisfactory launch and-recovery system which requires considerably more investment and testing.

General UV Observations

- **Need to develop UV Operational Test Beds to verify Common Control Systems, Open System Architecture, Interface Standards, and FORCEnet Interoperability**

- **UV Metrics Required (compare to manned systems)**
  - **Cost Savings and TOC**
  - **Manpower and Training Savings**
  - **Mission Effectiveness**
  - **Deployability**

- **Should Emphasize**
  - **Missions a Human Cannot Perform**
  - **Missions that reduce Operator / User Casualties**
  - **Alternative ways to Accomplish Mission**

- **UV Master Plans Deficient**
  - **Build upon experience from ACTDs, AWEs, FBEs, Operational/Combat Use, and Projects from other Services/Agencies**
  - **Include Integration, Netting, and Network Control**

GENERAL UNMANNED VEHICLE OBSERVATIONS

The panel made four primary observations regarding Naval UVs during the course of this study. The first observation was there is a lack of systems and architecture standards to deliver the required operational interoperability. To address this important issue, the panel recommends the development of Naval UV test beds to verify common control systems, open system architecture, interface standards and FORCEnet interoperability.   This approach would be similar to the joint test bed the Navy uses to verify battle group interoperability.

The panel also observed the lack of metrics addressing key aspects of UV systems versus manned systems, such as cost savings and total ownership costs, potential manpower and training savings, mission effectiveness and deployability. Metrics addressing these subjects should be developed in order to determine the size of investment to make in a family of Naval UVs.

As the DON continues to explore missions for Naval UVs the panel recommends emphasis on missions a human cannot perform and on missions that reduce operator and user casualties. Tactical development and employment should focus on alternative ways to accomplish missions by exploiting the unique capabilities offered by specific UV families, as opposed to simply replacing a manned system with an unmanned system and using conventional tactics.

Master plans exist in various levels of detail for unmanned aerial, ground and underwater vehicles. The UAV plan was found deficient in planned timing to incorporate lessons learned from current experiments and planned demonstration programs prior to making development commitments. In addition, all appear deficient in planning life cycle total ownership costs and for sustainment of the systems capabilities on a forecasted, reliability-centered maintenance basis throughout the planned system life. The Panel was

briefed that neither a master plan for USVs nor the USV Future Naval Capabilities (FNC) exists. The Panel believes that this latter point could be covered by a subset of the Autonomous Operations FNC.

Further, the panel did not find a coordinated Navy and Marine Corps plan to take advantage of the experience gained from experiments and demonstrations, including ACTDs, AWEs and FBEs. Experience gained from operational and combat employment also needs to be assessed and exploited to ensure unmanned systems are fielded with the interoperability required to support joint operations within the FORCEnet architecture.

Conclusions

- **Potential - Unlimited**

- **Quantitative Analysis and Metrics - Lacking**

- **Naval Programs - Not Coordinated or Focused**

- **Lessons Learned - Not Institutionalized**

- **Obstacles - Exist**
  - **Policy (ROE and Other)**
  - **Cultural**

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UV CONCLUSIONS

The combat potential for the use of UVs is virtually unlimited. The most persuasive arguments can be made for those areas augmenting the current force structure in areas where a unique contribution can be made---beyond the sense of the dull, dirty, and dangerous. UV systems can play a pervasive role in Persistent ISR, and as communications nodes in netcentric warfare may be a key element within FORCEnet. Such unique areas include, but are not limited to, exploration of caves and buildings, sensors for identifying the presence of NBC hazards, underwater surveillance, mine warfare, force protection, ship and port security, and operations in high intensity threat areas. Substantial reductions in warfighter risk are expected for time-sensitive strike missions and some elements of tactical reconnaissance. As such, Naval UVs, have the potential to form the backbone of future Naval operations, brought about by both the contribution of individual unmanned air, ground, underwater, and surface systems, as well as the netted contribution of these systems within FORCEnet.

The Panel observed the lack of any formal quantitative analyses to justify the investments in unmanned systems. The panel also found little in the way of metrics addressing the benefits of key aspects of unmanned systems in the areas of incremental total ownership costs, potential manpower, training, and cost savings (where replacing manned systems), as well as mission effectiveness and deployability. These kinds of metrics and quantitative analyses are considered essential to determine the most beneficial CONOPS for the initial and subsequent deployment of UVs.

The Panel found a plethora of Naval UV initiatives in development. Some are funded as technology initiatives under ACTDs and others are overhead funded efforts that involve platforms borrowed from industry. Additional efforts involve the purchase of commercial platforms with integration and experimentation funding coming from acquisition programs.

The Panel could not find a systematic and coordinated Navy and Marine Corps effort to take advantage of the experience gained from experiments and demonstrations, including ACTDs, FBEs, AWEs, or combat experience from "Desert Storm", "Enduring Freedom", and "Just Cause". There are repositories of "Lessons Learned" captured from the Fleet/Force Commanders to the Joint Staff, such as the Joint Universal Lessons Learned System (JULLS) and from Marine Corps experience captured in the Marine Corps Lessons Learned System (MCLLS), however, the Panel saw no mechanism to capture the lessons and apply them to quantitative analyses, war gaming M&S, or to the development of CONOPS, subsequent mission/systems requirements and UV "Master Plans". The Panel believes that such lessons learned need to be fully exploited to ensure that UVs are fielded with the interoperability required to support joint operations within the FORCEnet architecture and Sea Power 21.

Successful development of UVs faces cultural and policy issues in addition to those addressed above. Cultural issues include, for example, resistance to trusting a machine to perform tasks formerly performed by humans; insecurity resulting from humans being displaced by machines; rank being determined by the number of humans, not machines, commanded; platform centric paradigms; "stove-piped" development communities; and, bandwidth concerns.

One policy issue of note is that which relates to development and application of a common TCS. While TCS is being developed under Naval leadership, universal applications to all types of UVs is not evident in light of the continued development of unique ground segments for UAVs and UGVs. The Panel saw no evidence of the consideration of TCS for UUVs and USVs. Other policy issues that appear to cause some significant difficulty are those related to the fear of autonomous operations being too dangerous (or going "out of control") and thus becoming accident liabilities. Connected to this, ROEs and clearances for UAVs to fly in controlled airspace along with manned military and civilian aircraft are other significant policy issues that need to be continually addressed. Final areas of difficulty are acquisition and resource issues that promulgate "stove-piped" developments.

Recommendations

- **Create Integrated UV Master Plan (CNO/CMC)**

- **Conduct Independent Quantitative Analysis (CNO/CMC)**

- **Institutionalize Lessons Learned (CFFC/MCCDC)**

- **Create Integrated Management Structure to acquire UVs (ASN(RDA))**

- **Establish a policy for Open Systems Architecture and Modular Design approach, and Common Man/Machine Interfaces (SECNAV)**

- **Focus on Technology Obstacles for Next Generation UV Deployment (DASN/PEO/CNR)**

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RECOMMENDATIONS

To focus investment and speed the attainment of operational capability, the CNO and CMC should direct the creation of an integrated UV Master Plan. This effort will identify the requirements for initial applications and develop plans for integration of these systems into the Naval Force. While plans do exist for UAV, UUV, and UGVs, they have been developed in isolation by each of the constituencies associated with each UV type and without the benefit of the kind of analysis described below. In creating this integrated plan, it will be useful to consider the requirements from the Commandant of the Coast Guard.

The UV Master Plan must be accompanied by independent, quantitative analyses of the alternatives to conducting specific concepts of operations with and without UVs. The term *independent* implies that a systems integrator should not perform the analyses. A *quantitative* analysis would assign real numbers to the value and cost elements identified on page 21.

Since the integration of UVs into operational forces is relatively new, it is particularly important to capture the lessons learned from FBEs, AWEs, as well as operational and combat experience. The Panel recommends that CFFC and the MCCDC be made both the repositories for lessons learned and the action agents to ensure that they are implemented in the UV Master Plan, future exercises and in future systems.

The Panel is very reluctant to recommend any organizational changes. However, it is crucial that the DON creates an acquisition structure that incorporates and enforces an open systems architecture and modular design philosophy in the procurement of UVs. The panel deliberated at length about aligning the acquisition of UVs with the traditional Naval Force elements that will deploy the different UV types versus creating a "Czar for UVs." There is great utility in having the deployers be the acquirers. However, this organizational model is
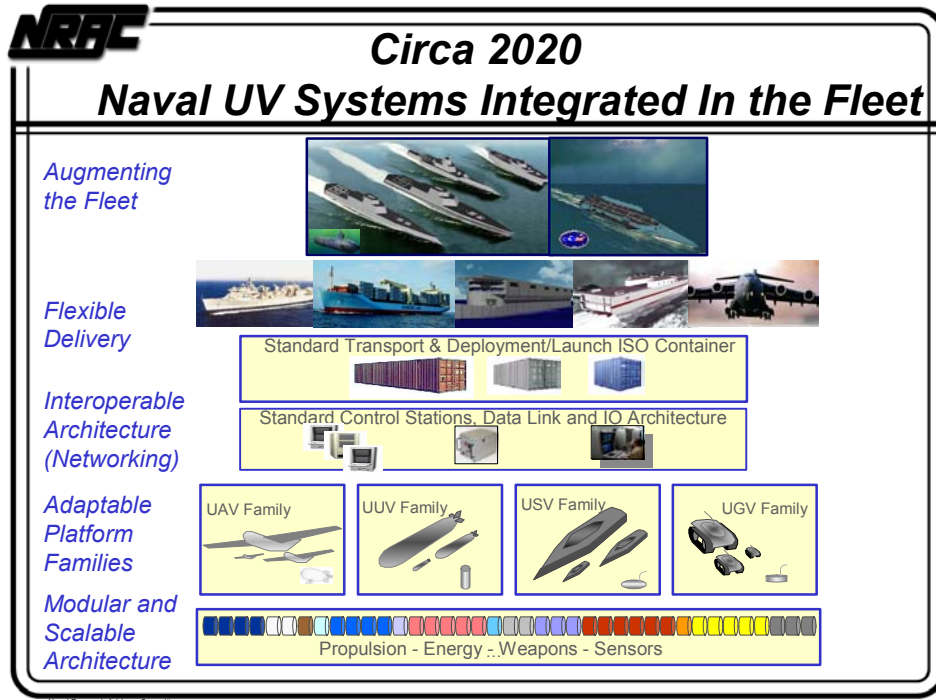
much less likely to institutionalize common control architectures, standard hardware interfaces, modular payload specifications, common man/machine interfaces, and interoperable communication systems and protocols. An effective approach to institutionalizing common control architectures, standard hardware interfaces, modular payload specifications, and interoperable communications systems and protocols has been to create systems integration test beds. The Panel recommends that the ASN(RDA) explore organizational alternatives and implement a management structure that will establish the design principles and standards, create and maintain the test beds, and enforce compliance.

Because the payoff in this area is so great, and the penalties so severe, the panel also recommends that the SECNAV establish a policy for an open systems architecture, a modular design philosophy, and common man/machine interfaces for the development, acquisition, and deployment of UVs.

With respect to technology, the Autonomous Operations FNC appears to be focused on near term UV S&T needs, however, there also appears to be a proliferation of other uncoordinated S&T efforts. The Panel recommends that S&T be focused on the following five highest priority technology enablers:

- Cooperative Adaptive Autonomous Controls

- Intelligent Information Management

- Secure, Robust Communications

- Energy Storage and Propulsion for Endurance

- Launch and Recovery Systems

Appendix C provides a more detailed discussion of these technology areas.

Circa 2020
Naval UV Systems Integrated In the Fleet

Augmenting the Fleet

Flexible Delivery

Standard Transport & Deployment/Launch ISO Container

Interoperable Architecture (Networking)

Standard Control Stations, Data Link and IO Architecture

Adaptable Platform Families

UAV Family | UUV Family | USV Family | UGV Family

Modular and Scalable Architecture

Propulsion - Energy - Weapons - Sensors

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CIRCA 2020

Understanding the Study's findings and recommendations, there is no question that the Fleet/Force of the future will be heavily dependent upon UVs (UVs). Many will be organic to surface and submarine combatants and many will be in a ready for issue role to fleet units, areas of responsibility and/or combat zones around the world. Development must be in compliance with an interoperable architecture and the networking necessary to integrate UVs into Sea Power 21's Sea Shield, Sea Basing and Sea Strike. From ISR to Littoral Sea Control, Homeland Defense and enhanced Seaborne Positioning, it will take a family of manned systems and UVs to get the job done.   A modular design policy within and across systems must also be required to provide flexibility proliferation and reduce cost. Whether it is propulsion, energy, weapons or sensors, flexible packages capable of covering the spectrum of mission areas are essential for battlespace management and warfighting success.

In this study, every effort was made to highlight the positives as well as point out the deficiencies that are preventing the Navy and Marine Corps from developing a focused approach. Without question the added capability of UVs that can effectively do the dirty, dull, dangerous and even impossible, in some cases, is mind-boggling. On the other hand, if not properly integrated into the Fleet/Force, UVs can become a warfighter's nightmare. That cannot be allowed to happen!

Implementation of these recommended actions will ensure that future Naval Forces have available to them an effective and affordable suite of UV systems that complement our manned capability and effectively respond to the ever changing threat and character of combat.

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Appendix A

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Terms of Reference

Role(s) of Unmanned Vehicles

NRAC Summer Study 2002

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Objective

Define possible UV operational concepts that will enhance warfighting effectiveness or introduce new naval capabilities. Review and assess operational concepts with respect to employment singularly or in swarms, level of autonomy, factors influencing operational capability including navigation, power, vulnerability and affordability.

Background

Over the past 20 years there has been a proliferation of UV research and development efforts and programs. The DOD is at the leading edge of a transition to growing reliance on UVs. Increasing demands upon operating forces in terms of tempo, increased threat capabilities, rules of engagement parameters and risk management are leading Naval forces, as well as other services, to the development of UVs. These UVs are envisioned to perform a variety of missions in many environments.

The most recent focus has been primarily on Unmanned Aerial Vehicles (UAVs). These early programs have focused primarily on various sensor systems hosted on a variety of different platforms (VTUAV, Globalhawk, PIONEER…) in the near term. Fleet operational integrated sensor and weapon delivery vehicles, Unmanned Combat Aerial Vehicles (UCAVs), have been deemed to be mid to far term capabilities. However, recent events in Operation Enduring Freedom, has stimulated interest in accelerating this capability.

A smaller but no less important area has been the development of Unmanned Surface and Underwater Vehicles (USVs, UUVs and UGVs). These efforts have been largely limited to primarily research and development programs with only a few maturing to potential Fleet employment, (RMS, LMRS, SAHRV). It is important to note that this form of underwater employment of UVs is less mature and not as robust as that of their aerial counterparts.

Specific Tasking

Review and assess potential concepts of operations (CONOPs) and employment (COE) of all Naval missions with respect to UVs. Examine the following:

- Fleet Needs (Command Capability Issues).
- Requirements (existing and perceived).
  - Reconnaissance/surveillance
    - Sea and land
  - Engagement
    - Sea and land
- Capabilities desired to meet CONOPS and COE
  - Required levels to meet study group recommended Fleet requirements for:
    - Autonomy
    - Communication
    - Navigation
    - Operations and support
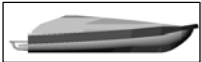
- ▪ Launch and recovery
- − Mission risk reduction
  - ▪ Personnel
  - ▪ Political (Rules of Engagement)
- − Discuss affordability as a function of meeting Fleet needs

Recommend which Operational Concepts and Employment Options are considered to have the greatest potential to improve warfighting capabilities and effectiveness, reduce manpower and cost of operations.

Systems Looked at by Subgroups

UAV	Mission	Phase	Example
BAMS	MARITIME PISR	CTD	
PIONEER	MAGTF ISR	OPNS & SUPPORT	
DRAGON EYE	TACTICAL ISR	S&T	
UCAV-N	PISR/STRK	S&T	

UGV			
GLADIATOR	MULTI-MISSION	CTD	
DRAGON RUNNER	MOUT RSTA	S&T	
RONS	EOD	OPNS & SUPPORT	
MDARS	PHYS SECURITY	SDD	

Appendix B

Systems Looked at by Subgroups (cont.)

USV	Mission	Phase	Example
SPARTAN	SUW	S&T	
ROBO SKI	FORCE PROTECTION	S&T	
OWL	MIW/ASW	S&T	
TARGET DRONES	TARGETS	OPNS & SUPPORT	

UUV			
RMS/LMRS	MIW	SDD	
REMUS	MIW	OPNS & SUPPORT	
SEAHORSE	OCEANOGRAPHIC	S&T	
SAHRV	VSW RECON	OPNS & SUPPORT	

LEGEND FOR PHASES	
S& T: SCIENCE & TECHNOLOGY	SDD: SYSTEM DEVLOPMENT & DEMONSTRATION
CTD: CONCEPT & TECHNOLOGY DEVELOPMENT	OPNS & SUPPORT: OPERATIONS & SUPPORT

Technology Emphasis Areas

- Cooperative Adaptive Autonomous Controls
  - Collision Avoidance
  - ATR

Autonomy can reduce the degree of human intervention needed, along with the associated timeline delays, to the extent allowed by the Rules of Engagement. The warfighting value of unmanned systems increases substantially with higher degrees of autonomy, up to and including "intelligent autonomy" that could lead to the ability to implement cooperative and responsive behavior between all types of UVs. The significant challenges lie in development of: command and control algorithms for both autonomous and cooperative behaviors; sensor fusing algorithms; secure wireless networks to operate in a hostile environment; and autonomous navigation capability reducing the dependence upon the Global Positioning System (GPS).

Improvements in navigation, combined with interpretation of fused position data (via sensors or communications) could provide for interactive cooperative operations, either reducing or eliminating the risk of collision with other vehicles or obstacles (man-made or natural).

Automatic target recognition limitations are linked to the ability to discriminate the target from background clutter. The degrees of autonomy provided by development of predictive and rule based algorithms can augment the mitigation of this problem for UVs. The ability to interpret fused sensor data, provide responsive behavior in a threat environment, and communicate with other in-theater UVs can provide combat systems to locate, identify, and prosecute targets.

- Intelligent Information Management
  - On-board processing; data compression

One of the principal technology challenges for wireless communications, command and control is reputed to be bandwidth. Technology development thrusts for information processing, and significant increases in local memory and computational speed brought about by chip development within the past few years are indicative of the viability of increased levels of on-board processing. Merging this hardware capacity with new software techniques, neural networks, and rule based algorithms sets the stage for an ever-increasing capability to process data on-board. Processing raw sensor data, fusing that data with other sensor and communications data, and then conversion of the processed data to information is a significant step in effectiveness. Development and application of data compression algorithms before transmission of the information can significantly reduce the bandwidth requirements. Bandwidth reduction thus gained may facilitate incorporation of secure, robust communication techniques.

- Secure, Robust Communications

Communications and networking between ground stations and UVs, between manned systems and UVs and between different UVs comprise a principal enabling capability for UV utility. While on-board processing and data compression will reduce the requirements for bandwidth, the need to provide redundancy and encryption for security and anti-jamming

will continue to drive network requirements. Examples of technologies for advanced communications links include Low Probability of Intercept (LPI) waveforms, satellite communications, and laser communications. The goal is a self-configuring and reconfiguring, mobile, wireless network architecture that is essential to enabling the FORCEnet concept. The challenge is in providing UVs with secure and robust links while at the same time recognizing that UVs provide the communications relay capability necessary for the concept of netcentric warfare.

- Energy Storage and Propulsion for Endurance

A significant attribute of UVs is the ability to stay on-station for periods that exceed human endurance. This is particularly true for the capability of Persistent ISR. Only energy storage and propulsion limit endurance for a UV. The principal gains to be made in energy storage are to be made in high energy density batteries, and higher density storable propellants. A significant technology base in both industry and the DoD addresses this requirement. An alternative technology to developing electric power is fuel cells in which technology developments are directed to hydrocarbon fuels instead of hydrogen.

In addition to electric drive, specific propulsion technology developments are required for both UV turbine engines and internal combustion engines. The follow on to the joint Integrated High Performance Turbine Engine Technology (IHPTET) program for turbine engine development has directed more resources to the class of engines appropriate for UAVs. Work on lightweight diesel engines should also make shipboard handling of UV fuels less demanding.

While advances in energy storage and propulsion will have a big impact on UV performance, the current capability is sufficient for operational utility.

- Launch and recovery systems

Technology maturation is required for launch and recovery systems to improve existing capabilities in the near term and leading to the ability to incorporate autonomous deployment of smaller UVs from a larger UV host. In the near term particular emphasis should be for fixed wing UAVs based on ships and carriers and for UUVs that are both submarine and surface ship based. Currently, the Automatic Carrier Landing System (ACLS) provides a hands-off capability for landing manned aircraft on a carrier. In practice, the system is used to augment a hands-on landing and there is insufficient confidence in the current system to employ it for the UCAV-N. In addition to improving the precision and reliability of the ACLS, procedures need to be developed that replicate the interaction between the Landing Signal Officer (LSO) and the pilot involving last second decisions on wave-off. A currently program under development, the Unmanned Common Auto-Recovery System (UCARS), has shown promise for both UCAV-N as well as for smaller UAVs such as Hunter and Pioneer.

Current UUV launch and recovery systems from surface ships are jury-rigged for the most part and create a time consuming process. The LMRS submarine launch and recovery system is effective but it takes up too many torpedo slots (nine) to be mission effective. Technology is required to significantly reduce the storage bay size and to provide an improved recovery system.

Appendix D

List of Briefings and Visits

<u>Briefings</u>

Sponsor Remarks	N81
MCM Programs	N75
Navy UAV Strategy	N78
Program Manager UAVs	PMA 263
USMC UAVs	HQMC
Surface Warfare UV Programs	N76
EOD Programs	N75
Naval Oceanography Command	
UUV Program	PMS 407
UCAV-N Resource Sponsor	N780X
DARPA	
Marine Corps UGVs	
NSWC Dahlgren Division, Carderock	

   USV Missions

   USV Missions – Innovation Center Project

   UUV Missions

   UGV Missions

   Cooperative UV CONOPS/Swarming UVs

SPAWAR Programs	
Coastal Systems Station	
N70 Perspective	
PEO Strike	
Lockheed Martin	
Boeing	
BAMS/UAV	N78
MCWL	
Raytheon	
US Army Aviation/Missile Command	
Northrop Grumman	
Autonomous Operations FNC	ONR

Appendix D

ONR UGV's & UUV's

Organic MCM   ONR

NUWC Programs

<u>Visits</u>

Special Warfare Programs

Special Program Office   Wright-Patterson AFB

Joint Unmanned Air Vehicles Joint Test and

   Evaluation Office (JUAV-JTE)   NAS Fallon

SPAWAR Systems Center   San Diego

Naval Undersea Warfare Center   Newport

Naval Warfare Development Command   Newport

Joint Forces Command   Norfolk

Strategic Studies Group   Newport

ACRONYMS

ACLS	Automatic Carrier Landing System
ACTD	Advanced Concept Technology Demonstrations
AOA	Abbreviated Operational Assessment
ASN(RDA)	Assistant Secretary of the Navy (Research, Development and Acquisition)
ATR	Automatic Target Recognition
AWE	Advanced Warfighting Experiments
BAMS	Broad Area Maritime Surveillance
C4I	Command, Control, Communications, Computers and Intelligence
CFFC	Commander Fleet Forces Command
CMC	Commandant of the Marine Corps
CNO	Chief of Naval Operations
CNR	Chief of Naval Research
COE	Concepts of Employment
CONOPS	Concept of Operations
DARPA	Defense Advanced Research Program Agency
DASN	Deputy Assistant Secretary of the Navy
DoD	Department of Defense
DON	Department of the Navy
DT	Developmental Testing
EMD	Engineering Manufacturing Development
ESG	Expeditionary Strike Group
FBE	Fleet Battle Experiment
FNC	Future Naval Capability
GPS	Global Positioning System
HQMC	Headquarters Marine Corps
IHPTET	Integrated High Performance Turbine Engine Technology
ISR	Intelligence, Surveillance and Reconnaissance
JFCOM	Joint Forces Command
JROC	Joint Requirements Oversight Council
JULLS	Joint University Lessons Learned System
LMRS	Long-Range Mine Reconnaissance System
LPI	Low Probability of Intercept
LRE	Launch and Recovery Element
LSO	Landing Signal Officer
M&S	Modeling and Simulation
MCCDC	Marine Corps Combat Development Command
MCE	Mission Control Element
MCLLS	Marine Corps Lessons Learned System
MCWL	Marine Corps Warfighting Laboratory
NAS	Naval Air Station
NBC	Nuclear, Biological and Chemical
NRAC	Naval Research Advisory Committee
NSAWC	Naval Strike and Air Warfare Center
NSWC	Naval Surface Warfare Command

NUWC	Naval Undersea Warfare Control
NWDC	Naval Warfare Development Command
ONR	Office of Naval Research
OPNAV	Office of the Chief of Naval Operations
OSD	Office of the Secretary of Defense
OT	Operational Testing
PEO	Program Executive Officer
PMA	Program Manager Air
PMS	Program Manager Surface
POM	Program Objective Memorandum
R&D	Research and Development
RMS	Remote Mine-Hunting System
ROE	Rules of Engagement
RSTA	Reconnaissance, Scouting, Target Acquisition
S&T	Science and Technology
SECNAV	Secretary of the Navy
SPAWAR	Space and Naval Warfare Systems Command
SPECWARCOM	Naval Special Warfare Command
T&E	Test and Evaluation
TCS	Tactical Control System
TOR	Terms of Reference
UAV	Unmanned Air Vehicles
UCARS	Unmanned Common Auto-Recovery System
UCAV	Unmanned Combat Air Vehicle
UGV	Unmanned Ground Vehicles
USV	Unmanned Surface Vehicles
UUV	Unmanned Underwater Vehicles
UV	Unmanned Vehicles
WPAFB	Wright-Patterson Air Force Base